Example:

The steel bed of a suspension bridge is 200 m long at 20°C. If the extremes of temperature to which it might be exposed are -30°C to +40°C, how much will it contract and expand?

(increase in length: 4.8 cm)
(decrease in length: 12 cm)

$\Delta T = T_2 - T_1$

① $L_0 = 200m$
$T_1 = 20°C$
$T_2 = -30°C$
$\alpha = 12 \times 10^{-6} (C°)^{-1}$

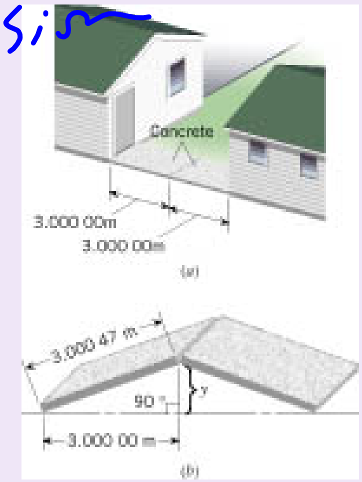
$\Delta L = \alpha L_0 \Delta T$
$\Delta L = (12 \times 10^{-6})(200m)(-50)$ ← C°
$\Delta L = -0.12 m$
$\Delta L = -12 cm$

② $T_2 = 40°C$

$\Delta L = (12 \times 10^{-6})(200m)(20C°)$
$\Delta L = 0.048m$
$\Delta L = 4.8cm$

Try: linear expansion
[Cutnell (Page 343)]

A concrete sidewalk is constructed between two buildings on a day when the temperature is 25°C. The sidewalk consists of two slabs, each three meters in length and of negligible thickness. As the temperature rises to 38°C, the slabs expand, but no space is provided for thermal expansion. The buildings do not move, so the slabs buckle upward. Determine the vertical distance y in part *b* of the drawing below. (0.053 m)

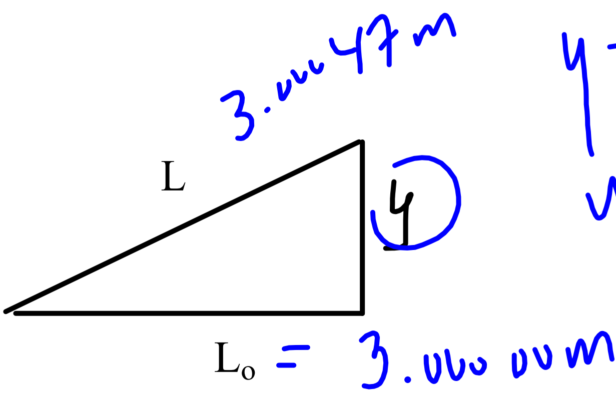


F12.11.jpg

$$\Delta L = \alpha L_o \Delta T$$

$$\Delta L = (12\times10^{-6})(3.00000)(38-25)$$

$$\Delta L = 0.00047\text{ m}$$



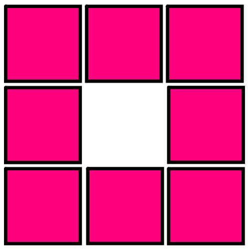
$$y = \sqrt{(3.00047)^2 - (3.00000)^2}$$

$$y = 0.053\text{ m}$$

☆

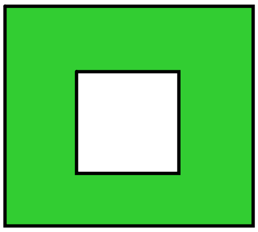
NOTE:

The diagram below shows eight square tiles that are arranged to form a square pattern with a hole in the center. If the tiles are heated, what happens to the size of the hole?

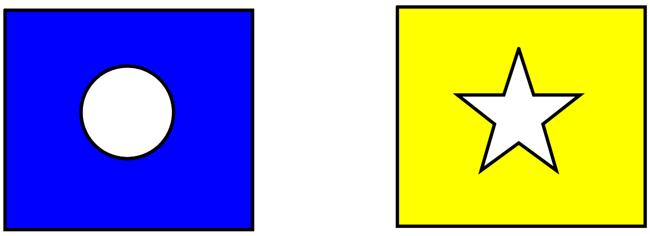


The hole in the pattern expands exactly as much as one of the tiles.

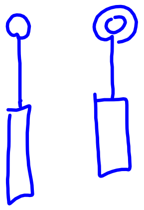
We could have used a square plate with square hole in the center. The hole in the plate would have expanded just like the hole in pattern of tiles.



The same conclusion applies to a hole of any shape.



A hole in a piece of solid material expands when heated and contracts when cooled, just as if it were filled with the material that surrounds it.



☆

Example:

An iron ring is to fit snugly on a cylindrical iron rod. At 20°C, the diameter of the rod is 6.445 cm and the inside diameter of the ring is 6.420 cm. To slip over the rod, the ring must be slightly larger than the rod diameter by about 0.0080 cm. To what temperature must the ring be brought if its hole is to be large enough so it will slip over the rod? (4.5×10^2 °C)

rod $d = 6.445\text{ cm}$

ring $d = 6.420\text{ cm}$

$6.445\text{ cm} + 0.0080\text{ cm} = 6.453\text{ cm}$

$$\Delta L = \alpha L_0 \Delta T$$

$$\Delta T = \frac{\Delta L}{\alpha L_0}$$

$$\Delta T = \frac{6.453 - 6.420}{(12\times10^{-6})(6.420)}$$

$$\Delta T = 428.35\ \text{C}^\circ$$

$$\Delta T = T - T_0$$

$$T = \Delta T + T_0$$

$$T = 428.35 + 20$$

$$T = 4.5\times10^2\ ^\circ\text{C}$$

Expansion in Two and Three Dimensions

When a material that cannot be approximated as a thin rod experiences a change in temperature, it also changes size. For example, if a flat plate of metal is heated, it gets both longer and wider. If a cube of metal is heated, it gets longer, wider and taller.

New parameters called the coefficient of area expansion, γ (gamma), and the coefficient of volume expansion, β (beta), are defined.

$$\Delta A = \gamma A_o \Delta T$$

$$\Delta V = \beta V_o \Delta T$$

γ

ΔL α ✓
ΔA γ ←
ΔV β ✓

To a good approximation,

$$\gamma \cong 2\alpha \text{ and } \beta \cong 3\alpha$$

Linear Thermal Expansion

Cutnell - C12, Page 366

* Do not use α values for SD's.

$$T = 2\pi\sqrt{\frac{l}{g}}$$

Coefficients -> Page 342

#9. 0.084 m
#11. 1.5×10^3 m
#12. b) 17/10000 or 0.0017
#13. 108.2 C° *
#15. -2.82×10^{-4} m
#17. 49°C
#19. 2.0026 s (need extra digits to see change in period)